DESCRIPTION

METHOD AND DEVICE FOR DETERMINING
MOTOR VEHICLE ACCELERATION

The present invention concerns a method and device for determining acceleration of a motor vehicle.

It is of course known to measure vehicle acceleration by means e.g. of some form of accelerometer, or alternatively by measuring the speed of the vehicle wheels and differentiating with respect to time. Unfortunately the vehicle, due to its suspension etc., and the driveline, due to its compliance, have dynamics exhibiting resonance at frequencies which can be as low as 2Hz in motor cars and still lower in larger vehicles. This can create corresponding oscillation in measured acceleration signals. Signal noise can also be a problem. The signal can be filtered to improve its quality but a filter with a time constant long enough to remove the low frequency oscillation would introduce an appreciable time lag.

The problem is experienced in connection with electronic systems for control of vehicle powertrains. The present invention has in fact been developed for use in a system which controls a powertrain using a continuously variable transmission of so-called "torque controlled" type (the term is known in the art and transmissions of this type have for example been described in European patent 832376 and its US counterpart US 6071209, both granted to Torotrak (Development) Limited). In such transmissions variator ratio is not directly set, but instead transmission ratio is able to change in accordance with changes in engine and vehicle speed. To determine rate of ratio change, vehicle acceleration is required. The rate of ratio change is needed for various purposes in controlling the powertrain. If a simple low pass filter were used with a long enough time constant to remove the low frequency oscillation from a measured value of vehicle acceleration, the speed of response of the control system would be unacceptably compromised.

In accordance with a first aspect of the present invention there is a method of determining acceleration of a motor vehicle, comprising obtaining a high pass filtered acceleration signal and a low pass filtered acceleration signal, one of the filtered

acceleration signals being obtained based upon net driving force applied to the vehicle and the other being obtained by measurement, and adding the two filtered acceleration signals to obtain an output signal representing vehicle acceleration.

Specific embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings in which:-

Figure 1 is a block diagram of a software-implemented filtering strategy embodying the present invention;

Figure 2 is a more detailed representation, again in block diagram form, of an actual filter used in the Figure 1 strategy; and

Figure 3 is a graph showing actual and measured vehicle speed values (vertical axis) against time (horizontal axis).

The embodiment of the invention to be described below provides improved quality signals representing both vehicle speed and vehicle acceleration and does so by using a combination of measured and predicted vehicle speed/acceleration values.

A predicted vehicle acceleration value is obtained on the basis of the force applied by the motor vehicle's powertrain and brakes. In Figure 1 the variable TrqWhlEst, input at box 10, represents an estimated, unfiltered value of the torque applied to the driven wheels of the motor vehicle by the powertrain, obtained from an electronic model of the powertrain. Dividing this torque by the rolling radius of the vehicle driven wheels at 12 gives a value for the force applied by the powertrain to accelerate the vehicle (ForceDrive). To allow for the additional force applied by the brakes, the brake pressure is measured and braking force (ForceBraking in Figure 1) is then calculated based upon the pressure/force characteristics of the brakes. The relationship between brake pressure and brake force is essentially linear, so that this is a straightforward calculation. The function labelled 14 in Figure 1 receives ForceBraking and ForceDrive, as well as indications of direction of vehicle travel (forward/reverse) and of the position of the vehicle drive control, and in dependence upon these outputs a corrected value ForceBrakingCorr of the brake force. Adding this at 18 to ForceDrive gives an unfiltered signal ForceVehEstRaw representing the net driving force being applied by engine and brakes to accelerate the vehicle.

This signal ForceVehEstRaw is passed to a multiple order filter 20, which is seen in more detail in Figure 2 and comprises a series of low pass, first order, digitally implemented filters 22 for filtering the net driving force signals ForceVehEstRaw, as well as a further series of identical filters 24 for filtering a vehicle speed signal, as will be explained below. The output of one filter such as 22 is fed to the input of its neighbour 22' and so on in the series, so that together they provide a high order, low pass filter with a relatively sharp frequency cut off and a time constant TC, a common parameter which is input to the filters.

The term "low pass filter" is well understood by those skilled in the art and is used here in its conventional sense, to refer to a filter which passes signal components below a chosen frequency (dictated by the time constant) but discriminates against higher frequencies. The term "high pass filter" will also be used herein and is again used in its conventional and well understood sense to refer to a filter whose transmission band extends upwards from a chosen frequency, lower frequencies being discriminated against.

The output from the filter 20 is a low pass filtered, estimated value ForceVehEstFilt (Figure 1) of the force acting upon the vehicle. At 26 this is taken from the unfiltered value ForceVehEstRaw to provide what is in effect a high pass filtered version ForceVehEstHPFilt. This is then input to an adaptive model 28 of the vehicle. The model serves to output a high pass filtered estimate AccVehEstHPFilt of the vehicle acceleration.

The simplest possible model 28 would involve only division of the driving force ForceVehEstFilt by the vehicle mass. For greater accuracy it is necessary to take account of vehicle mass, road gradient, drag and potentially other factors. Mass and gradient are of course variable and are not directly measured. Hence a more sophisticated model is adaptive, making corrections to these variables based upon the vehicle's response.

AccVehEstHPFilt has been obtained based upon the vehicle mass and the force applied to it. Another way to obtain a value for vehicle acceleration is to measure vehicle speed and then differentiate with respect to time. In Figure 1 the

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measured vehicle speed, itself a signal which incorporates a good deal of noise, is indicated as SpdVeh at 30 and is input to the multiple order filter 20 and specifically to the series of filters 24. The resulting low pass filtered signal is passed to a digital differentiator 32 to provide a low pass filtered estimate AccVehFiltRaw of the vehicle acceleration.

At 34 the high pass filtered signal AccVehEstHPFilt is added to the low pass filtered signal AccVehFiltRaw to provide at 35 an output signal AccVehFilt which is a very close approximation to the true value of the vehicle acceleration, as trials have demonstrated. The low frequency noise due to drive line oscillation has been removed by virtue of the low pass filtering of the measured vehicle speed signal. The time lag introduced by the low pass filter has been corrected by addition of the high pass filtered estimate of acceleration based upon the transmission/brake force.

To now explain how a usable value of vehicle speed is obtained, note that the low pass filtered value of vehicle acceleration AccVehFiltRaw, obtained by differentiation of measured vehicle speed, is led to a multiplier 36 which also receives the time constant TC of the multiple pass filter 20. Multiplying AccVehFiltRaw by TC gives an offset SpdVehFiltOfst which is an estimate of the difference between the actual and filtered values of the vehicle speed introduced due to the time lag from the filter 20. Adding this offset at 38 to the low pass filtered measured vehicle speed signal, SpdVehFiltBase gives an improved, filtered vehicle speed signal SpdVehFilt.

Figure 3 is intended to make the significance of the offset SpdVehFiltOfst clear. V_A represents actual vehicle speed and in this example is a straight line corresponding to constant vehicle acceleration. There is a time lag, determined by the time constant TC, between the actual speed V_A and the measured, filtered signal V_{FILT}. Consequently at an arbitrarily chosen point in time, t_0, the value SpdVehFiltBase of the filtered signal V_{FILT} is different from the actual speed Spd. The difference is in the illustrated example equal to the gradient of the filtered signal V_{FILT} multiplied by the time lag TC. Adding the offset SpdVehFiltOfst, calculated as explained above, thus gives a value thus SpdVehFilt which is equal to the true

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value Spd. The offset is precisely correct in this example only because the vehicle acceleration is constant. If the acceleration varies then there will be some discrepancy between SpdVehFilt and Spd, but the method provides a great improvement over the raw filtered value.

A reset function 42 receives the measured and the filtered vehicle speed signals SpdVeh and SpdVehFilt and resets the filter 20 when these indicate that the vehicle is stationary. All of the functions illustrated in Figures 1 and 2 are typically carried out by a suitably programmed microprocessor.